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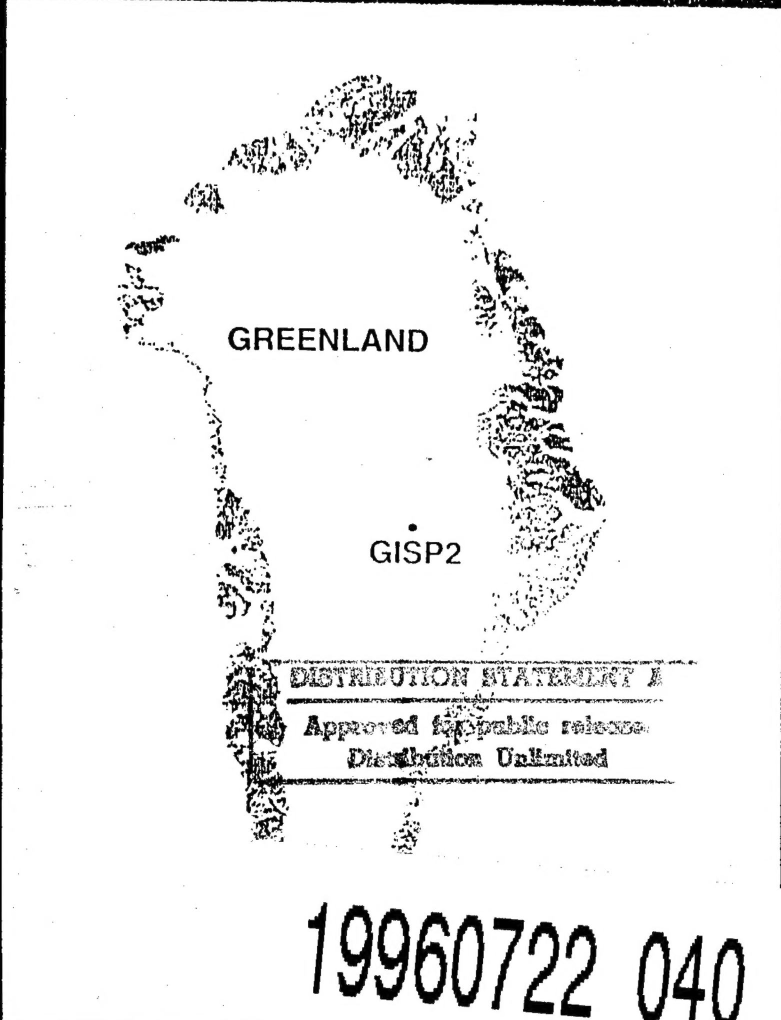

In this issue:

Proceedings of the Japan-Russia-United States Study Group on Dumped Nuclear Waste in the Sea of Japan, the Sea of Okhotsk, and the North Pacific Ocean

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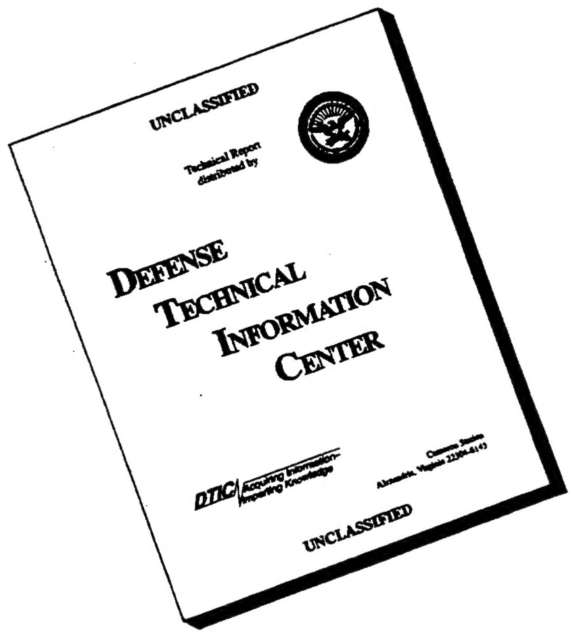

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The region of interest for this Study Group and the known radioactive waste disposal areas are shown in Figure 1. Known waste sites occur in the Sea of Japan (also known as the East Sea), the Sea of Okhotsk and the North Pacific off the Kamchatka Peninsula. Other sites may be located later as additional information on the radioactive waste disposal problem becomes known.

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U.S. Geological Survey

Descriptive Physical Oceanography of the North Pacific, Sea of Japan (East Sea) and Sea of Okhotsk

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The region of interest for this Study Group and the known radioactive waste disposal areas are shown in Figure 1. Known waste sites occur in the Sea of Japan (also known as the East Sea), the Sea of Okhotsk and the North Pacific off the Kamchatka Peninsula. Other sites may be located later as additional information on the radioactive waste disposal problem becomes known.

Important oceanographic considerations in this region as applied to the problems of nuclear waste disposal and disposed nuclear waste remediation include:

- Bathymetry, or water depth;
- Sea bottom composition;
- Currents;
- Fronts;
- Wave fields; and
- Ice cover

as well as biological and biochemical factors whose complex impacts can only be generally mentioned here.

The first consideration, water depth, is of particular importance if bottom-resting wastes are to be inspected or if remediation efforts such as recovery or enclosure are to be undertaken. Present engineering capabilities for inspection and handling extend to depths of up to 3 km (A. Watt, SubSea International, personal communication, 1995), but such activities are much cheaper and easier in shallower water. Shallow disposal locations may present certain negative complications, however. Shallow water provides less local dilution capability in the case of liquid wastes or leaking bottom-resting wastes, and storm waves may penetrate deep enough to dislodge or damage bottom-resting wastes in very shallow regions. Water depth also influences the local biota. Deep open ocean areas typically are relatively sparsely populated by living organisms, both in the water column and on the bottom, while shallow nearshore regions are usually much more productive and often are heavily fished or otherwise exploited by people, opening up the possibility of contamination of human food sources.

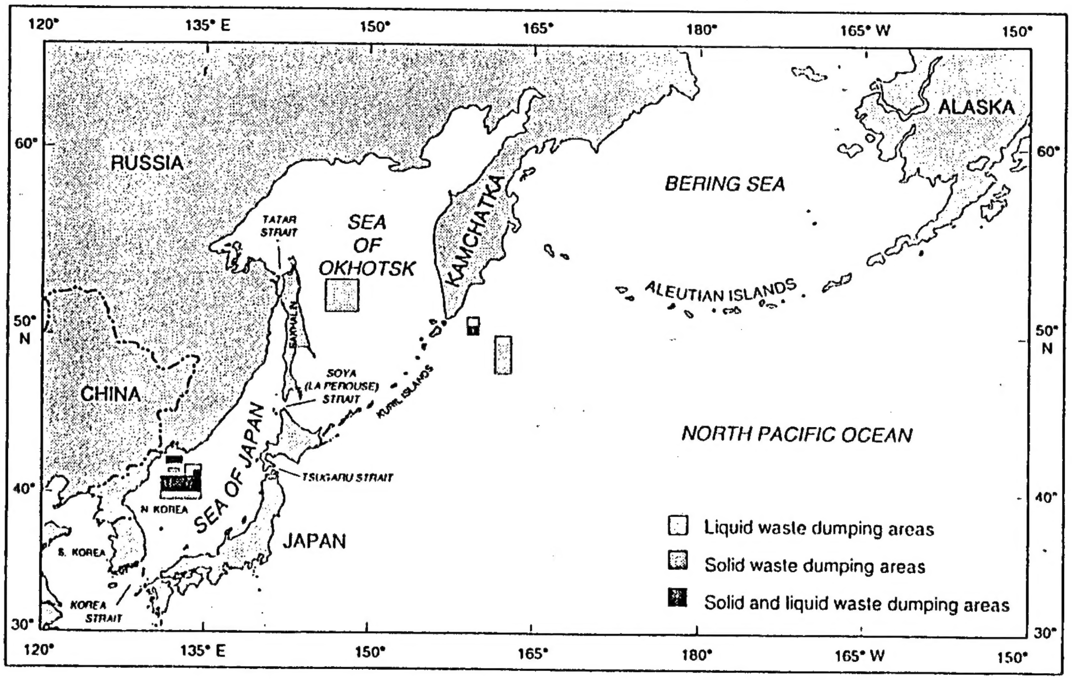

Figure 1. Geography of the area of interest in the North Pacific, Sea of Japan (East Sea) and Sea of Okhotsk and the known radioactive waste disposal areas. (From Yablokov et al. 1993.)

The area bathymetry, with details for the Sea of Japan and the Sea of Okhotsk, are presented in Figures 2–4. Known solid radioactive waste dumping sites lie in water up to several kilometers deep in the Sea of Japan and off the Kamchatka Peninsula, although some of the Sea of Japan wastes may have been deposited on the shallower shelf off North Korea. If deep disposal did take place, the deep sites may prove difficult and expensive for monitoring or retrieval or other remediation

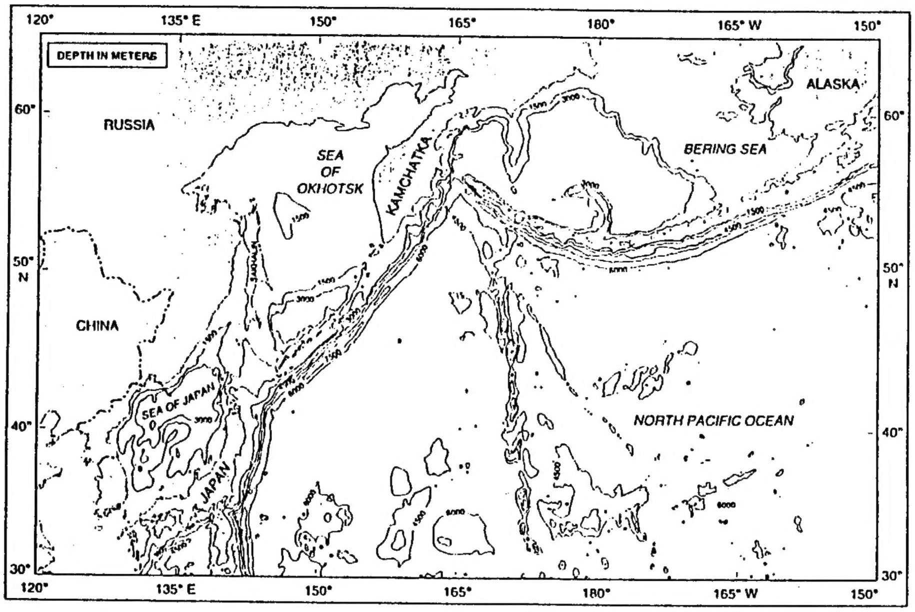

Figure 2. General bathymetry of North Pacific and adjacent seas. Depths are in meters. (From U.S. Naval Oceanographic Office bathymetry database "DBDB5.")

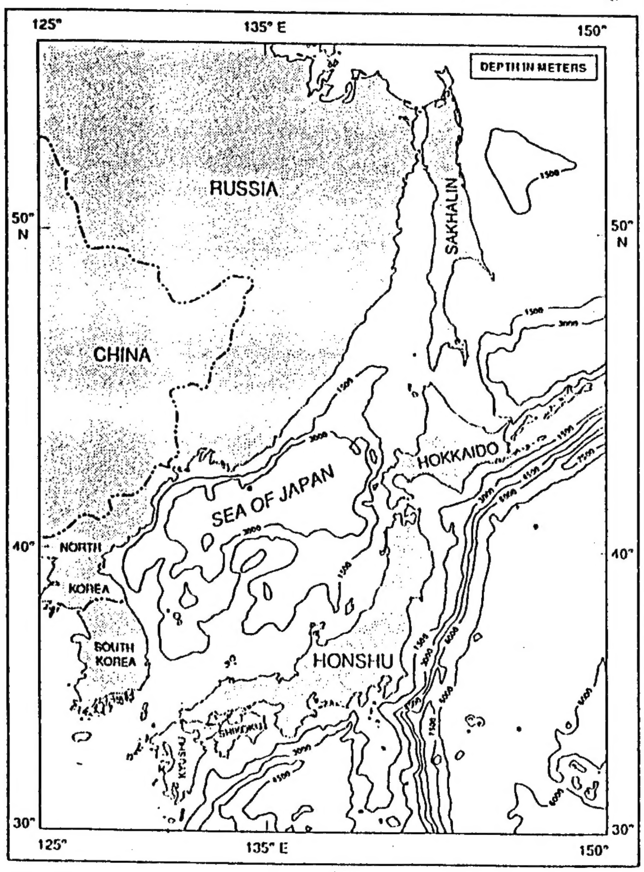

Figure 3. Detailed bathymetry in the Sea of Japan. Depths are in meters. (From U.S. Naval Oceanographic Office bathymetry database "DBDB5.")

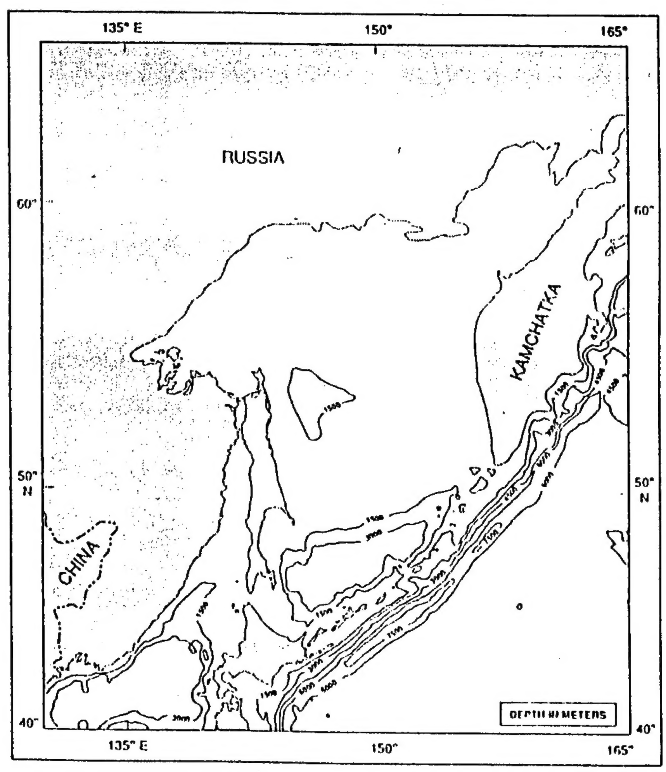

Figure 4. Detailed bathymetry in the Sea of Okhotsk. Depths are in meters. (From U.S. Naval Oceanographic Office bathymetry database "DBDB5.")

efforts. However, in the case of bottom-resting wastes in the Japan Basin of the Sea of Japan, the expected very slow vertical mixing and transport out of the deep basin would suggest any leakage would be confined to the Basin itself. In the North Pacific off the Kamchatka Peninsula, the disposal site appears close to the tectonically active subduction zone of the Kuril Trench. While earthquakes, submarine landslides and turbidity currents in such an area could potentially damage containers that enclose radioactive wastes, much of any resulting leakage might also be expected to remain localized in the deep trench. Because any leakage from bottom-resting nuclear wastes in these deep areas would be anticipated to remain confined to the deep basins, the wastes probably present a low-level near-term hazard. However, if the disposal locations are inaccurately known and the wastes are actually situated on the shallower shelf or slope regions, transport outside of the local region may indeed readily occur.

The second consideration, sea bottom composition, affects the type and quantity of biota present, thus affecting the impact of wastes on the local ecology and the paths and rates of transfer of nuclides through the food chain. The chemical interactions that take place between various waste products and different sediment types such as organic material, fine clay, mud, sand, gravel, etc., are known to affect physical transport mechanisms and the rates and paths of chemical species through the food chain. Different sediment types also impact natural burial of bottom-resting wastes and the ease or difficulty with which in-situ remediation efforts may take place. Natural burial would occur more readily, for example, in deep, soft mud than in sandy gravel. General surface sediment types in the Greater North Pacific region are shown in Figure 5. From this figure, solid radioactive wastes appear to have been dumped in regions of mud and of mud and sand. Actual inspection and sampling at individual disposal sites would be required for more specific and accurate knowledge of the relevant bottom composition and the implications of that composition.

Disposal of liquid wastes and leakage of contained bottom-resting wastes have chemical and ecological consequences in the immediate area. Effects outside of the immediate disposal area will depend largely on physical transport by ocean currents. Both the direction and, particularly in the case of short-lived isotopes, the speed of transport are important. For liquid wastes disposed of near the surface, surface currents are the most important factor, while near-bottom currents will disperse bottom-resting wastes.

Oceanic fronts are boundary zones between water masses of different characteristics, often separating different current regimes. Across these zones, certain characteristics of the water, such as temperature, salinity or nutrients, change significantly over short horizontal distances. Frontal regions typically are areas of increased biological productivity and hence often sites of concentrated human fishing activity. Disposal of pollutants near frontal regions or transport into frontal regions can thus potentially have serious ecological and human health implications.

Estimates of dispersal of near-surface wastes from the dumping sites may be obtained by examining the average near-surface current regimes of the region. To a first approximation, wastes would be expected to be transported at a speed and in a direction given by these currents. The physical transport of pollutants disposed at the locations of Figure 1 may be estimated through examination of Figures 6–9, the climatological surface currents for the area and their approximate speeds for both summer and winter. Care must be exercised in using conclusions

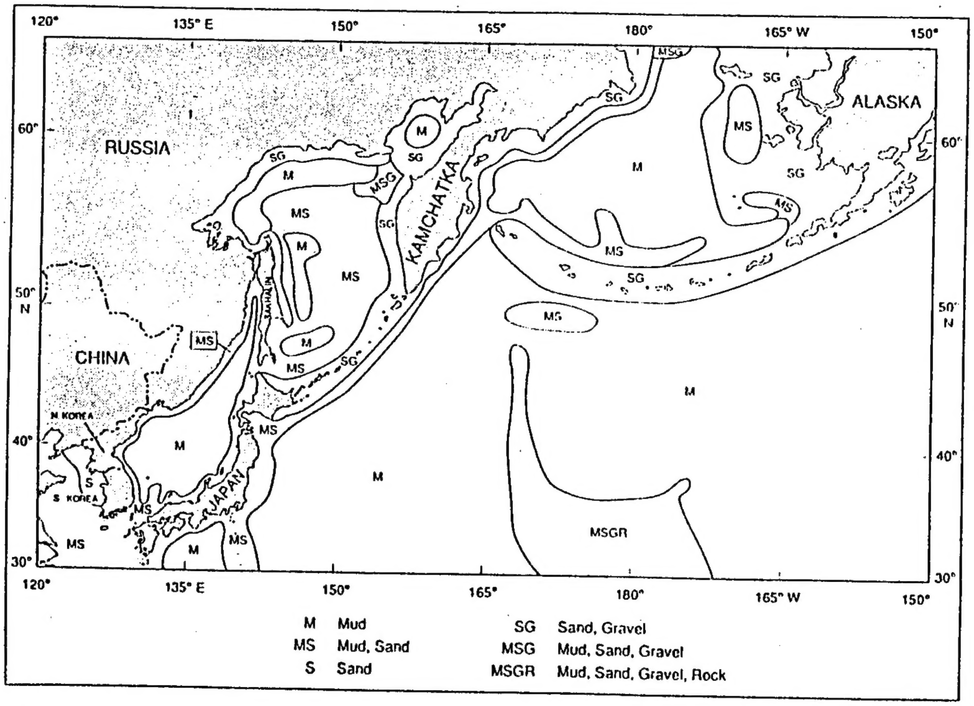

Figure 5. General surface sediment types in the North Pacific and adjacent seas. (From U.S. Navy Hydrographic Office 1951, Naval Oceanographic Office 1978.)

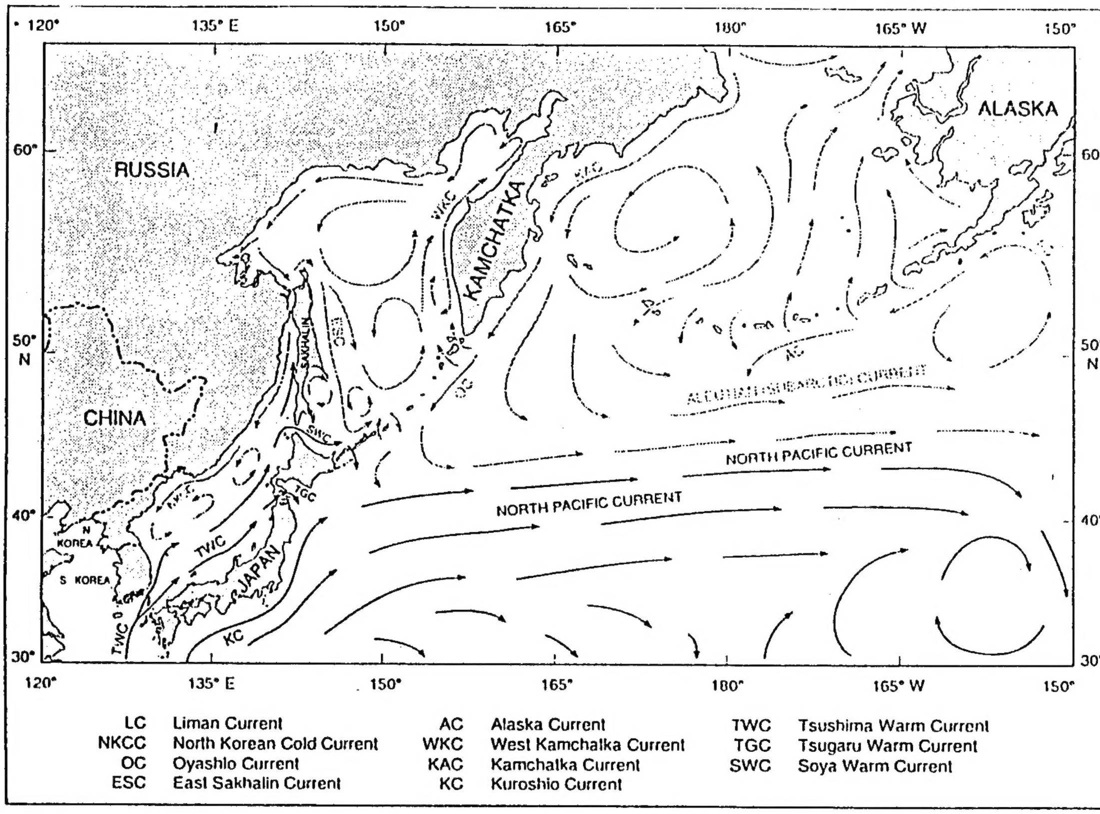

Figure 6. General large-scale ocean circulation in summer in the North Pacific and adjacent seas. (From Defense Mapping Agency 1989, U.S. Department of Commerce 1961.)

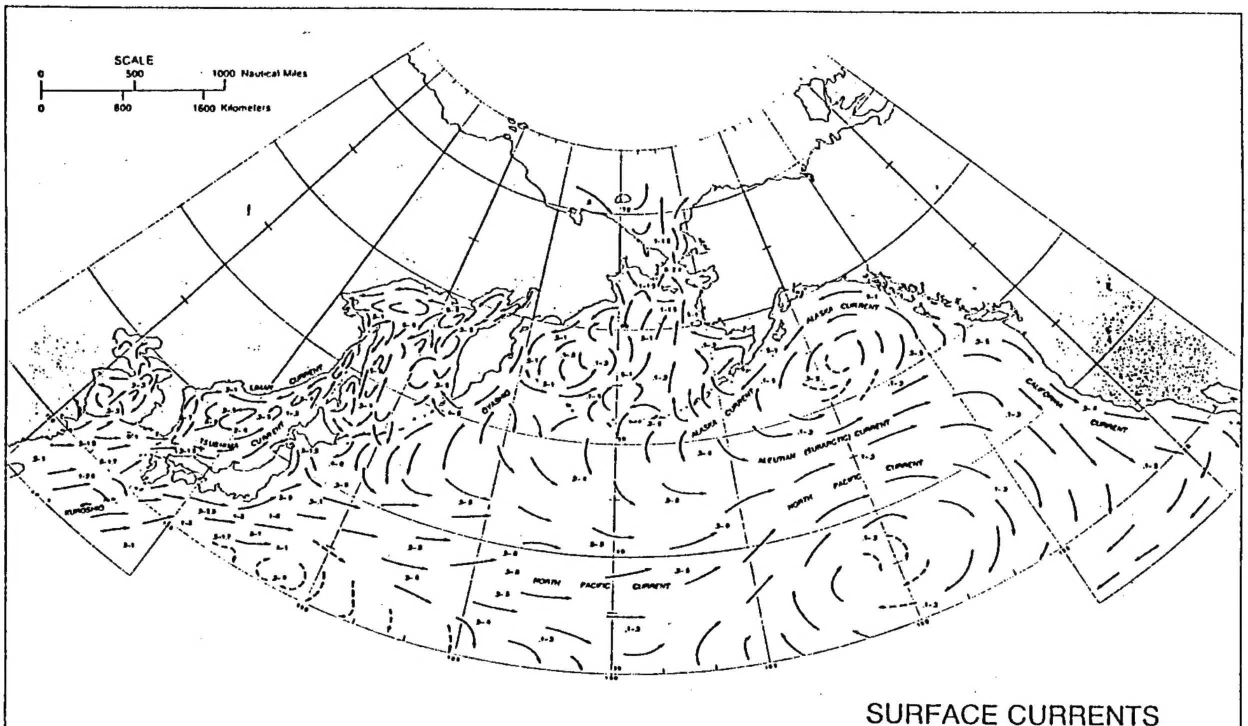

Figure 7. Approximate mean speed (kt) and direction of main ocean surface currents in the North Pacific and adjacent seas in summer. (From U.S. Department of Commerce 1961.)

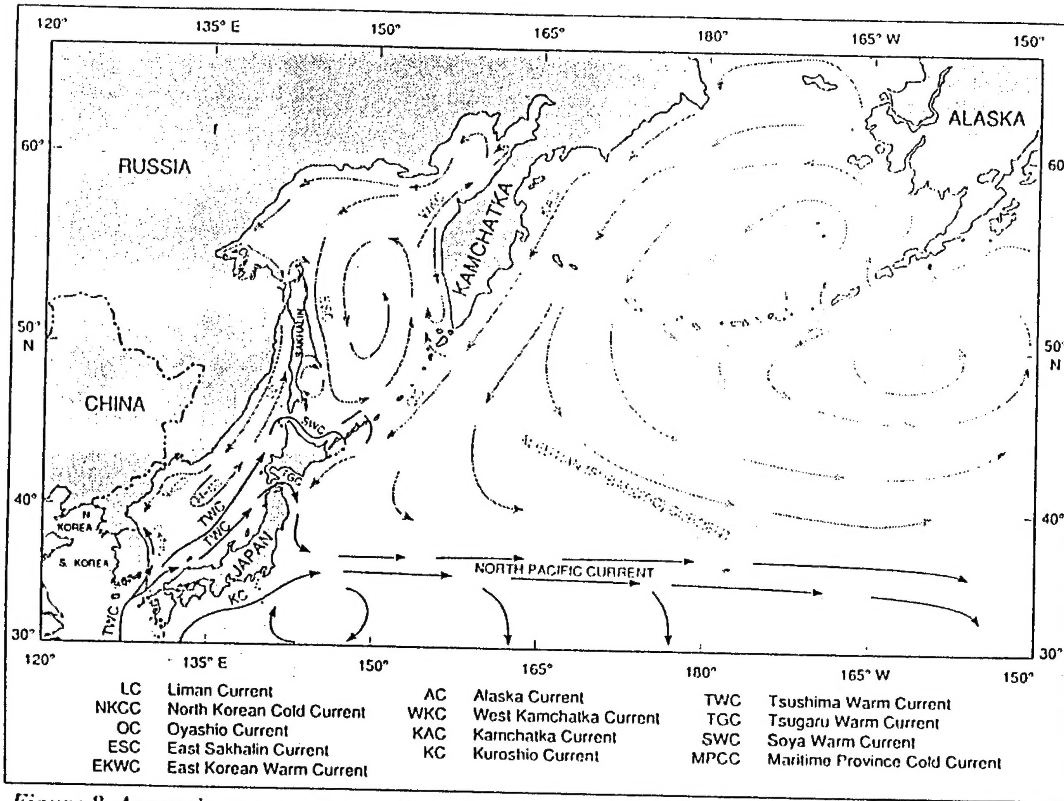

Figure 8. Approximate mean speed (kt) and direction of main ocean surface currents in the North Pacific and adjacent seas in winter. (From U.S. Department of Commerce 1961.)

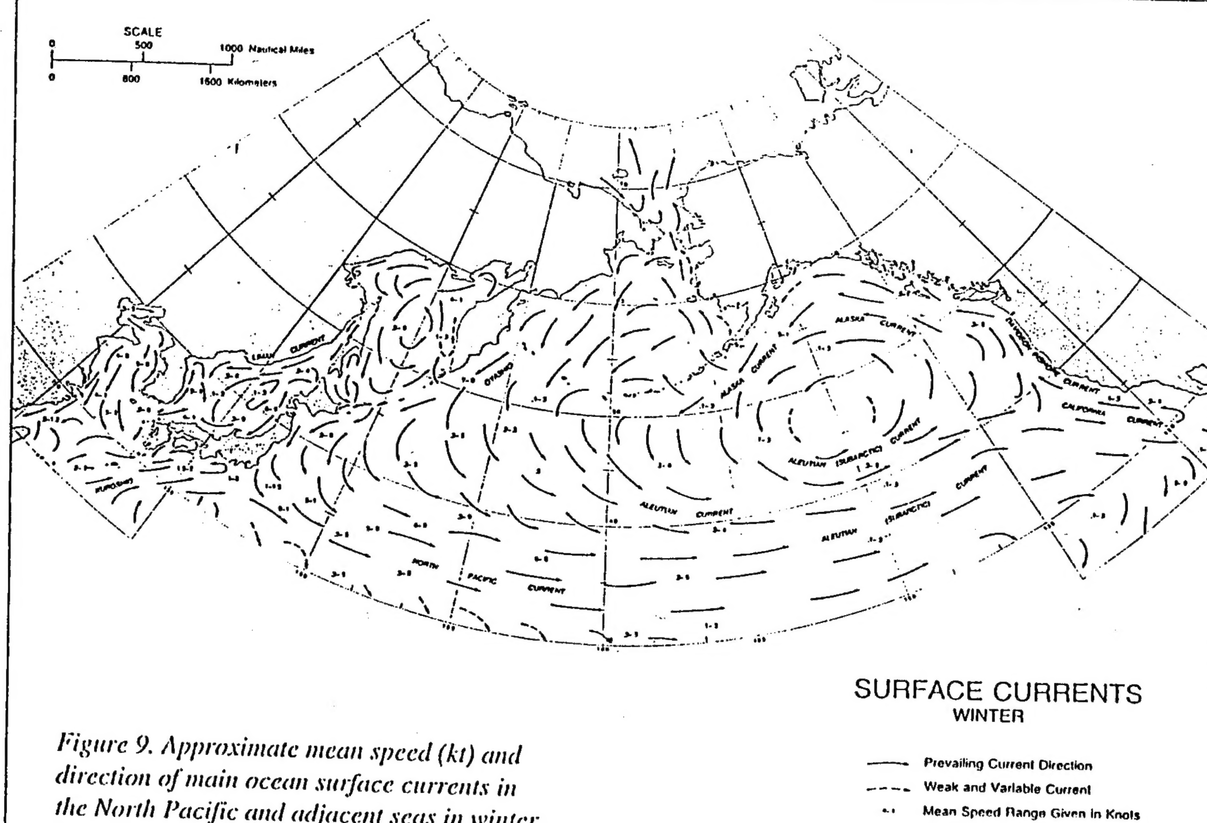

Figure 9. Approximate mean speed (kt) and direction of main ocean surface currents in the North Pacific and adjacent seas in winter. (From U.S. Department of Commerce 1961.)

drawn from these climatologies, however, as the currents are highly smoothed averages in time and space of what would be expected at any particular instant or location. Any conclusions are likely to be more accurate over the longer terms of months and years than over the shorter terms of hours, days or weeks.

The potential for radioactive concentration in the biota of frontal zones may also be estimated by correlating expected physical transport of wastes from various sites with the locations of frontal regions. The climatological positions of the frontal zones in the study area are given in Figures 10 and 11. The same caveat holds for climatological frontal positions as for climatological current patterns: climatologies are not necessarily accurate descriptions of instantaneous conditions.

Examination of these figures leads to the following expectations for physical transport and frontal concentration of surface-disposed nuclear wastes in this region over the longer term. Some liquid wastes dumped in the Sea of Japan are likely to be caught up in the North Korean Coastal Current and carried to the coast of North Korea. Others may be caught up in the Tsushima Warm Current and be carried to the coasts of Honshu and Hokkaido. Concentration in the biota of the Japan Sea Polar Front or the Tsushima Front is possible. In the Sea of Okhotsk, liquid wastes will potentially be transported by the East Sakhalin Current to the eastern coast of Sakhalin and down to the Kuril Islands and possibly into the Oyashio and out into the North Pacific via the North Pacific Current. Concentration of radioactive nuclides in the biota of the Soya, Kuril and perhaps West Kamchatka Fronts is possible. Liquid wastes disposed of off the southern coast of Kamchatka are likely to be carried into the North Pacific via the Oyashio and the North Pacific Currents. Having drawn these conclusions from oceanographic conditions, it must also be noted that the ecological and human health significance of these expectations will depend upon the magnitude of the dumping and the half-lives of the constituent isotopes and their chemical and biological pathways.

Very little relevant information was found for the region regarding near-bottom currents, which will govern the dispersal of leaking bottom-disposed wastes. Inspection or remediation of bottom-disposed wastes will be impacted by local currents, including tidal currents, which may be quite different in both direction and magnitude from the larger-scale climatological currents, which will control the long-term transport characteristics. Additional measurements of near-bottom currents on both short and long time scales will be necessary to properly assess the difficulties associated with monitoring and remediation or the significance of any leakage.

Finally, the feasibility of inspection or recurrent monitoring of disposal sites will be dependent upon the accessibility of the sites to inspection vessels. Wave heights and sea ice extent are important considerations. Temporary wave conditions in a local area which are unsuited for particular operations may be generated at any time by the passage of storms and atmospheric fronts, which can usually be predicted shortly in advance by weather reports. Winter will usually be the time of most frequent and most extreme unsuitable wave conditions, and a feel for the

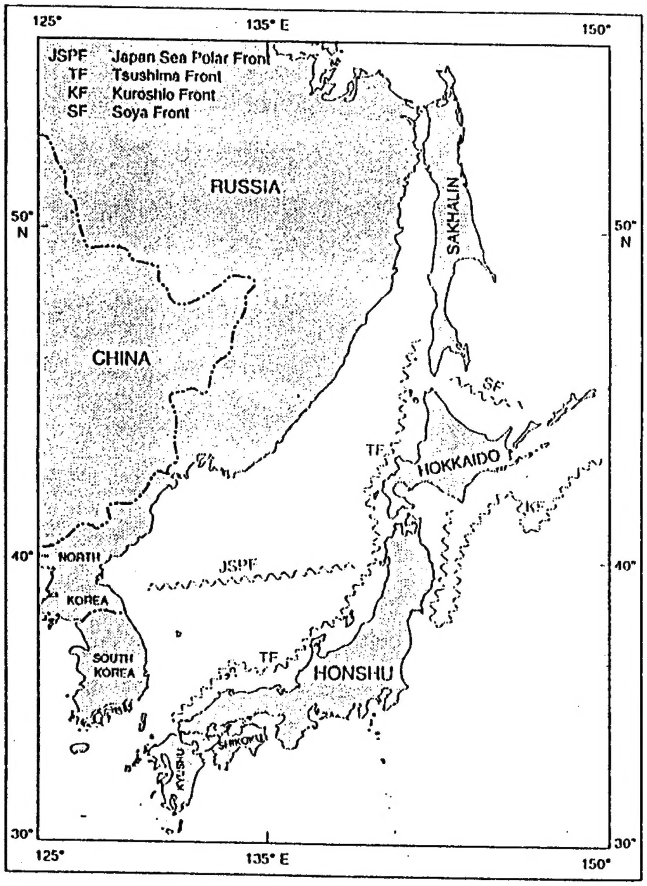

Figure 10. Approximate positions of the main ocean frontal regions in the Sea of Japan (East Sea). (From Tomczak and Godfrey 1994.)

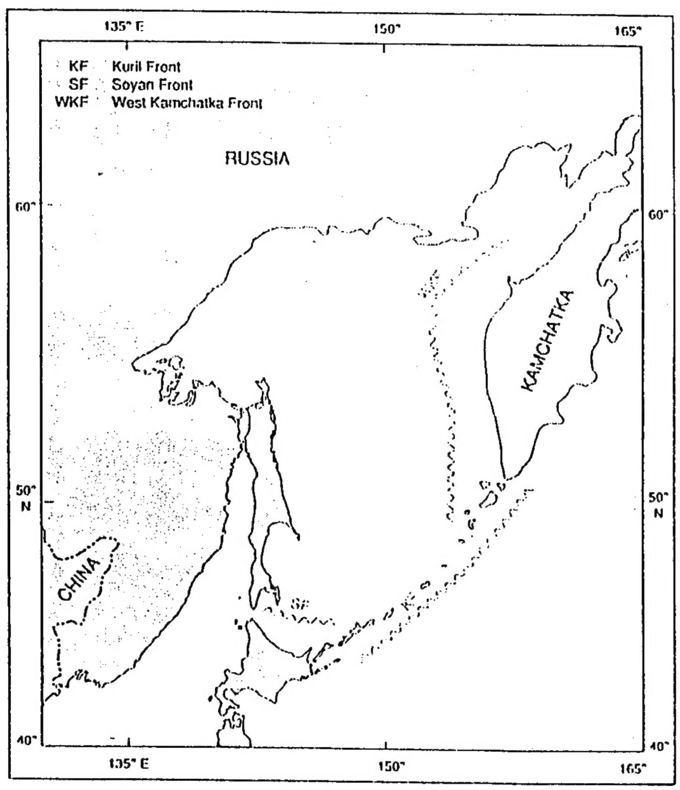

Figure 11. Approximate positions of the main ocean frontal regions in the Sea of Okhotsk. (From Tomczak and Godfrey 1994.)

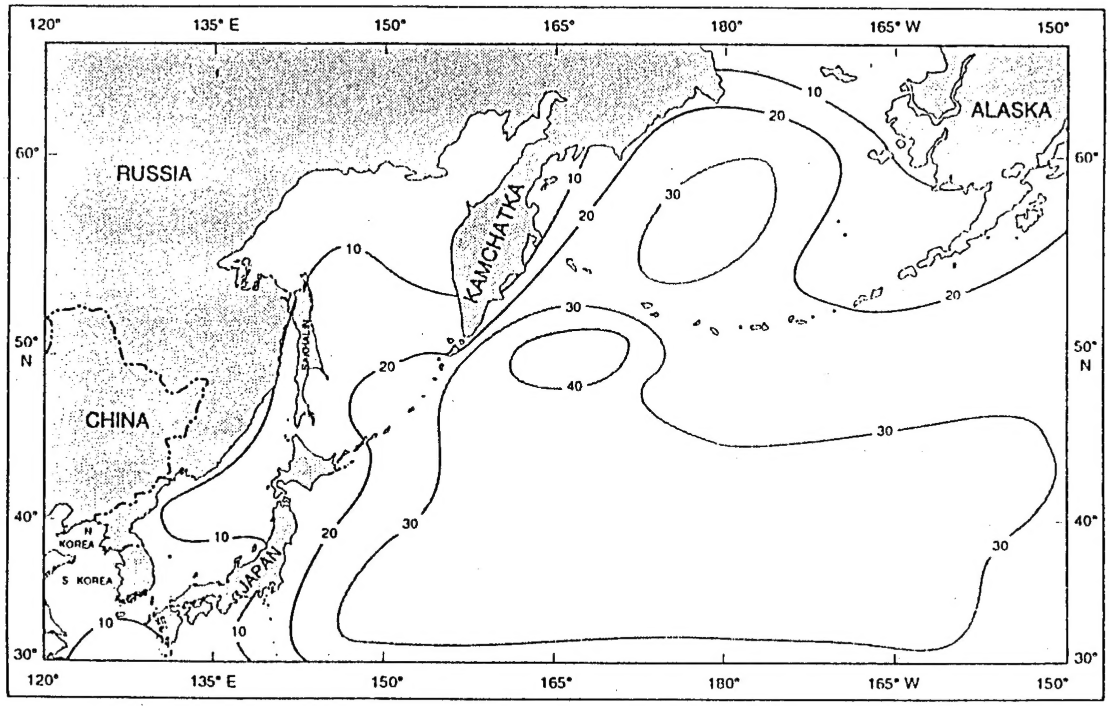

Figure 12. Percent of the time waves reach or exceed 3.5 m (12 ft) in height in winter in the North Pacific and adjacent seas. (From Defense Mapping Agency 1989.)

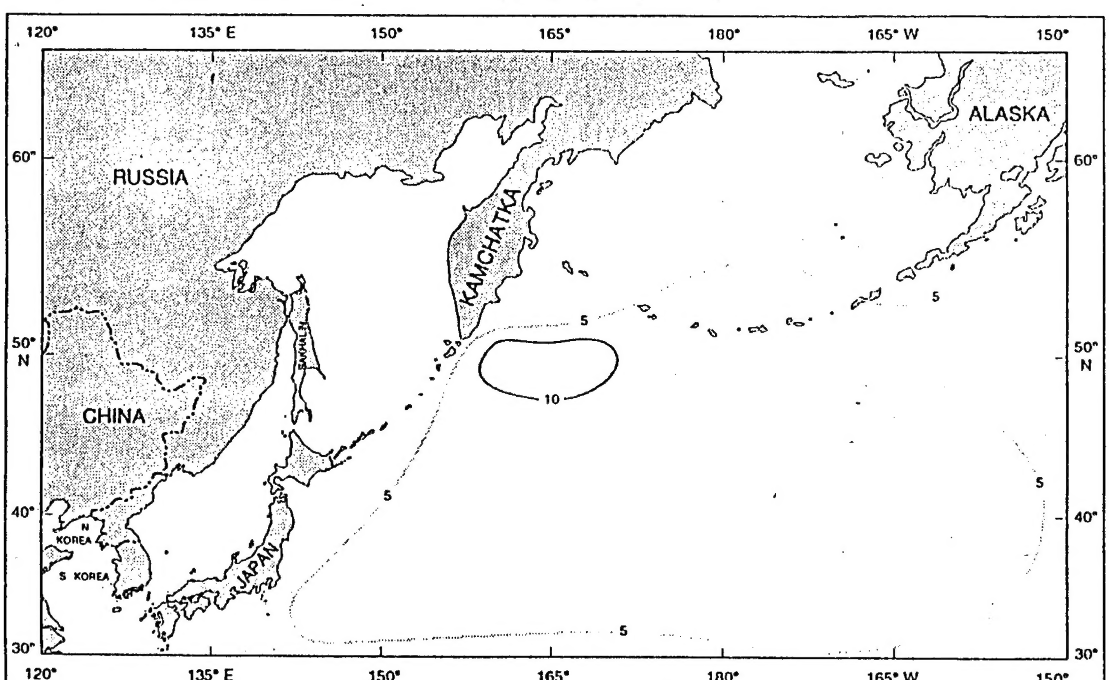

Figure 13. Percent of the time waves reach or exceed 6 m (20 ft) in height in winter in the North Pacific and adjacent seas. (From Defense Mapping Agency 1989.)

regions most likely to experience high wave conditions can be obtained by examining climatological charts of how often winter waves exceed some height, such as 12 feet or 20 feet (Fig. 12 and 13). From these figures can be seen that the most frequent high wave conditions are expected in the unprotected North Pacific off Kamchatka, where between 20% and 40% of the time waves higher than 12 feet are likely. Such waves are only expected 10–20% of the time in the Sea of Japan and the Sea of Okhotsk.

Maximum sea ice extent is shown in Figure 14. Sea ice is expected to be extensive in the Sea of Okhotsk and off Kamchatka. On-site inspection is likely to be hazardous in the areas in winter (as would be any disposal operations). Sea ice also presents another transport mechanism for suspended or dis-

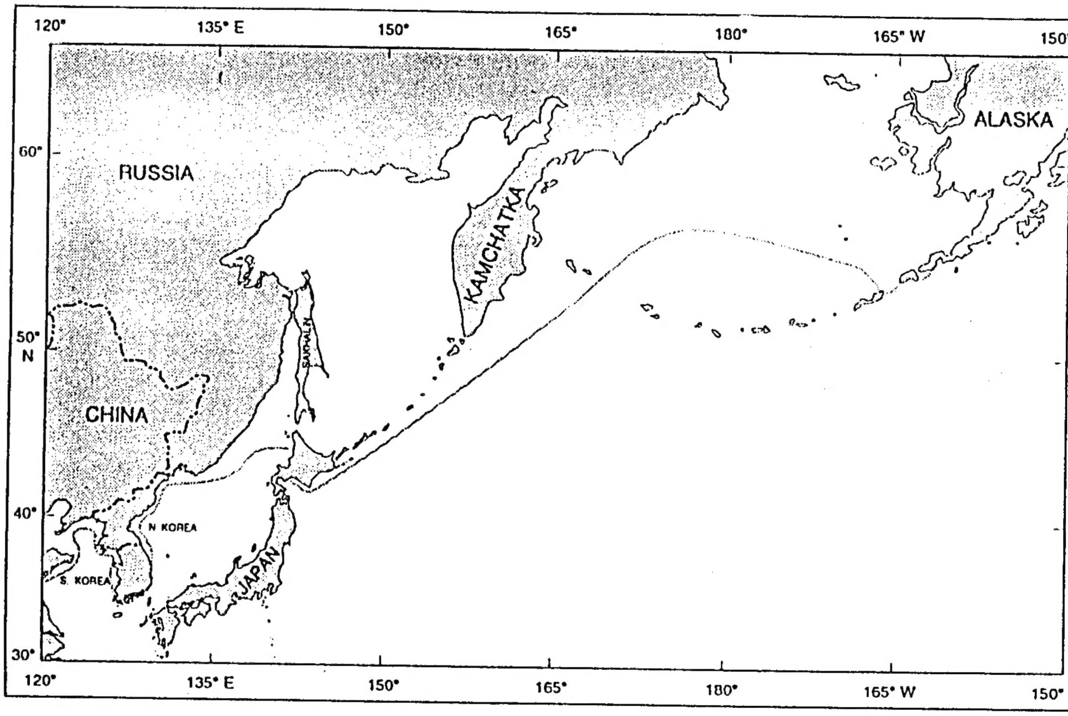

Figure 14. Maximum extent of sea ice in the North Pacific and adjacent seas in winter. (From U.S. Department of Commerce 1961.)

solved wastes, with the transport paths likely to be governed roughly by the winter climatological surface current patterns.

In summary, the oceanography of the Greater North Pacific region will strongly affect both the impact of pollutants on the natural and human ecology of the area and the difficulties inherent in monitoring, retrieving or minimizing the impact of disposed wastes, including nuclear wastes. Our knowledge of this area is sufficient to make some general statements about expected longer-term transport pathways, possible impacts, and difficulties in inspection and remediation, but there is no assurance these general statements will be accurate over the short term and in specific, localized cases. Each dump site would have to be examined in greater detail before policymakers could be supplied truly reliable information upon which to base decisions. However, it cannot be too strongly emphasized that these after-the-fact studies and efforts are far less desirable than reasoned before-the-fact studies and efforts. Before any disposal of hazardous materials takes place in the ocean, a realistic and thorough assessment should be made to select a suitable site and to gain a knowledge of such factors as likely current transports, bottom composition, and biological and geophysical pathways. Plans should be made before-the-fact for post-disposal monitoring and, in the case of contained wastes, for responses to both slow and catastrophic releases. It may sometimes be impossible to formulate satisfactory after-the-fact plans.

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